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EXISTING CONDITIONS

AT

WASTE DUMPS

JACKPILE-PAGUATE MINE, CIBOLA COUNTY,

NEW MEXICO

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I. GENERAL DESCRIPTION:

Mining activity at the Jackpile-Paguate Mine, operated by the Anaconda Copper Company, has led to the development of numerous waste dumps at the mine-site. Removal of overburden at the Jackpile-Paguate Mine at a stripping ratio of 25 tons of waste per ton of mill-feed (Dames and Moore, 1979) requires that temporary and permanent storage dumps be made for the waste materials. Aside from the pit highwalls, these waste dumps are the most conspicuous features of disturbance at the mine-site. Dumps FD-2 and several others at the southeast part of the mine-site are visible from Interstate Route 40, and so constitute an aesthetic impact. Of greater environmental importance is concern over mass stability of the waste dumps, and their susceptibility to accelerated erosion due to steep, unconsolidated slopes. This report will detail existing conditions at the waste dumps, with an emphasis on description of dump slope erosion.

There are 32 waste dumps at the Jackpile-Paguate Mine; their locations are given in Figure 1. The dump areas cover 1,266 acres, or approximately 48 percent of the total disturbed area of the mine (Anaconda, 1980). Dumps at the Jackpile Pit area comprise 720 acres; dumps near the South Paguate Pit comprise 355 acres; and dumps near the North Paguate Pit cover 191 acres. The material comprising the dumps consists of stripped

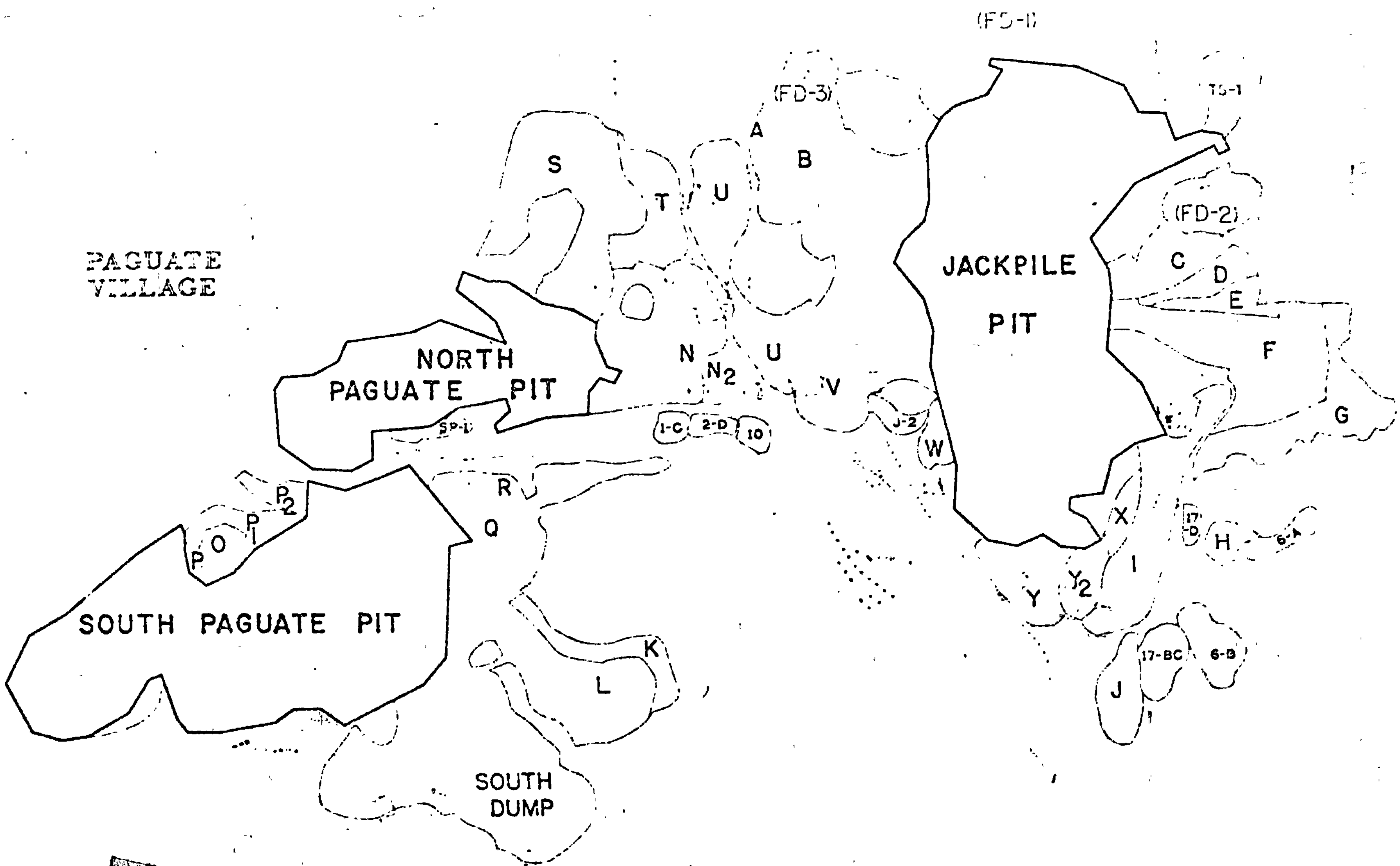

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FIGURE 1 - Waste Dump Locations at the Jackpile-Paguate Mine

overburden (Mancos Shale and Dakota Sandstone), barren Jackpile Sandstone, and ore associated Jackpile Sandstone. Records detailing the type, percent, and radiological content of material in each waste dump do not exist. Therefore, analysis of risks associated with erosional exposure of waste dump material is difficult.

The waste dumps have been constructed to approximate the mesa-like landforms that naturally occur in the vicinity of the mine-site (Dames and Moore, 1979). Overburden is dumped at the crest of the dumps, and forms an external slope at or near the angle of repose for the dump material. Waste dump heights range from 25 feet at R Dump, to 230 feet at FD-2 Dump (Anaconda, 1980). Slope percent ranges from 25 percent at S Dump, to 100 percent at South Dump (Anaconda, 1980). Table 1 gives slope percent, height of dump, and length of dump slope at 19 locations on 13 critical dumps from Anaconda (1980) cross-sections.

Information on precise age of waste dumps does not exist, since Anaconda records do not detail dates of dumping. However, conversations with Anaconda engineers have yielded approximate age relations among several critical waste dumps. The oldest waste dump at the mine-site is Y Dump (mid-1950's), while the youngest is FD-3 Dump (late 1979). Approximate dates of the most recent modifications of waste dump slopes are given in Table 2.

TABLE 1

WASTE DUMP DIMENSIONS. CROSS-SECTION LETTERS REFER TO THOSE IN VOLUME 3 OF ANACONDA (1980)

DUMP	CROSS-SECTION	SLOPE PERCENT	HEIGHT	SLOPE LENGTH
South	AA'	100	90 Ft.	127 Ft.
South	BB'	100	140 Ft.	198 Ft.
South	CC'	63	60 Ft.	112 Ft.
SP-1	DD'	78	31 Ft.	51 Ft.
R	EE'	100	25 Ft.	35 Ft.
T	FF'	77	100 Ft.	164 Ft.
N	GG'	89	80 Ft.	120 Ft.
N	HH'	77	46 Ft.	76 Ft.
N	II'	50	40 Ft.	89 Ft.
N2	JJ'	60	30 Ft.	58 Ft.
FD-3	KK'	90	130 Ft.	195 Ft.
U	LL'	75	60 Ft.	100 Ft.
U	MM'	60	60 Ft.	117 Ft.
V	NN'	80	215 Ft.	345 Ft.
V	OO'	71	150 Ft.	258 Ft.
SP-2	PP'	89	40 Ft.	60 Ft.
Y	QQ'	72	115 Ft.	196 Ft.
Y2	RR'	75	150 Ft.	249 Ft.
I	SS'	75	120 Ft.	200 Ft.
Three	)	75	120 Ft.	200 Ft.
Slope	)	80	40 Ft.	64 Ft.
Segments	)	67	20 Ft.	36 Ft.
FD-2	UU'	65	230 Ft.	423 Ft.

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TABLE 2

APPROXIMATE DATES OF MOST RECENT MODIFICATIONS ON SEVERAL CRITICAL WASTE DUMP SLOPES. OFFICIAL AGE RECORDS DO NOT EXIST. DATES REPORTED HERE CONSTITUTE "BEST-GUESS" ESTIMATES OF ANACONDA ENGINEERS

DUMP	DATE LAST MODIFIED
Y	1954 or 1955
Y2	Early 1960's
N	Early 1970's
S	Early 1976
F, G, V, J	1977
L, K, I	1978
T, FD-1, FD-2	1978 or 1979

Approximately 485 acres on 17 waste dumps have been reclaimed to date (Anaconda, 1980). Table 3 details the reclaimed dumps, acreage involved, and type and amount of cover used. Revegetative success has been quite varied. Waste dump tops have been revegetated with some success, due to gentle slopes and good water retention. However, revegetation of waste dump slopes has been a failure due to steepness of slopes and resultant vulnerability to erosional soil loss (erosional response of slope angle will be addressed in a later section). Revegetation attempts on dump slopes have been carried out only at J, I, and T Dumps. Therefore, the waste dumps listed in Table 3 as "reclaimed to date" should not be considered successfully reclaimed, since slopes have not been revegetated. Due to the significant height, long slope lengths, and steepness of slope angles at the waste dumps, erosional susceptibility and possible exposure of radiological hazards are environmental concerns at all waste dumps at the mine-site. However, certain waste dumps are potentially more vulnerable to erosion, and these will be examined in detail. These are:

1. V, FD-3, Y (long, steep slopes).
2. T, N, U (steep slopes; proximity to Rio Moquino).
3. South Dump (steep slopes).
4. Y, Y2, I (long, steep slopes; proximity to arroyos).
5. J (radiological hazard; proximity to arroyos).

TABLE 3

WASTE DUMPS RECLAIMED TO DATE (FROM ANACONDA, 1980)

Dump	Acres		Type of Topdressing Cover	Amount of Cover
C	21		THS*	24"
D	14		THS	24"
E	12		THS	24"
F	73		Mixture THS & some shales	18"-24"
G	49		Mixture THS & some shales	18"-26"
X	9		THS	18"-24"
I**	57		Mixture THS & some shales	18"-24"
Y_2	15		THS	18"-24"
L	40	(18 acres left to reclaim)	THS	24"
K	22		THS	24"
S	96		THS	24"
T**	27	(5 acres left to reclaim)	THS	18"-24"
O,P, P1,P2	35		THS	24"
J***	15		THS	18"-24"
	485			

*THS = Tres Hermanos sandstone. THS possesses the most favorable characteristics for vegetation establishment of the soil types present at the Jackpile Mine.

**Due to planned slope modifications, portions of these reclaimed dumps will be disturbed, requiring subsequent additional reclamation.

***To be relocated

II. WASTE DUMP SLOPE EROSION:

It has been noted that erosion is greatly accelerated on mine waste dumps in the western United States. Ringen, et al (1979) concluded that sediment yield from unreclaimed spoils piles at a coal mine in northern Wyoming was 11 times that of surrounding natural land. Wells and Rose (1981) found that runoff on disturbed, unrehabilitated slopes was 32 times more, and infiltration was 1-1/2 times less than on undisturbed or reclaimed areas. Lusby and Toy (1976) found that sediment yield from a reclaimed slope (3:1 slope) was more than twice that derived from the natural terrain.

Generally, it is agreed that the processes responsible for this increased erosion on spoils piles are (Lusby and Toy, 1976):

1. Greater mean slope.
2. Greater runoff.
3. Loss of root network density.

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Schumm (1956), in a study of badland erosion - analogous to waste dump slope erosion - in New Jersey, documented erosion processes in relation to slope angle. On 10-degree slopes, the coarser grains are exposed as the fine-grained particles are carried away; this tends to armor the slope, thereby reducing erosion. On 30-degree and steeper slopes, medium and fine-grained particles moving downward jam between larger grains forming check dams. The weight of water and sediment ponding behind these dams breaches them, forming a pulse of water - a surge-flow - which is capable of moving large particles, and forming rills and gullies.

Rates of erosion of hillslopes are related in a complicated fashion to numerous interrelated variables. The Universal Soil Loss Equation (U. S. Soil Conservation Service, 1981) describes erosion rate as a function of amount, frequency, and intensity of rainfall; soil characteristics, slope percent, slope length, vegetative cover, and ground cover in general. The relative importance of each of these variables to erosion rate is unclear. However, for slopes on which sheetwash is not an important mechanism, Schumm (1956) concluded that hillslope water flow divides itself due to the action of check dams, coarse grains, and vegetative material. This subdivision of flow - and resultant dissipation of energy - reduces velocity to a constant value regardless of slope length. Schumm's conclusion was that with rainfall, vegetative cover, and soil characteristics held constant, slope angle rather than slope length is the factor which primarily influences the rate of erosion.

Dames and Moore (1979) states that the waste dumps at the Jackpile-Paguate Mine blend in with the natural topography surrounding the mine-site, and that gentle slopes and low height have engendered (erosional) stability to the dumps. However, visual inspection of the dumps reveals that slopes are steep, heights are large, and erosion is occurring at a rapid rate. All waste dump slopes are traversed by numerous rills (less than six inch deep channels) and many have been cut by gullies (greater than six inch deep channels). Deep gullies have cut into the largest of the dumps. Dump I has been severely gullied at three localities, as has Dump V. South Dump contains one prominant gully. Table 4 gives gully dimensions at I and V Dumps. Photographs of these gullies are given in Figures 2 through 6.

Two approaches were used in this study to describe and quantify erosion occurring on waste dump slopes at the Jackpile-Paguate Mine. Firstly, the Universal Soil Loss Equation (USLE) was used to quantify erosion losses from sheetwash and small rill erosion on several critical waste dump slopes. Secondly, field measurements of the frequency, width, and depth of rills and gullies at several waste dump slopes of different age and slope dimensions were made.

A. Sheetwash and Small Rill Erosion:

The Universal Soil Loss Equation (USLE) is a tool initially developed to predict soil loss on cropland and, therefore, to evaluate the success or failure of soil conservation practices. Recent developments in the USLE have made it a potentially valuable tool in predicting soil losses and planning reclamation procedures for lands disturbed by surface mining in the western United States (Environmental Protection Agency, 1977).

The USLE is an empirically developed equation which relates soil loss to amount, frequency, and intensity of rainfall, soil characteristics, length of slope, slope angle, and vegetation or ground cover:

$A = RK\ (LS)\ C\ P$

A = Soil loss in tons/acre/year

R = Rainfall factor

K = Soil erodibility

TABLE 4

GULLY DIMENSIONS AT DUMPS I AND V

DUMP	LOCATION	POSITION MEASURED	WIDTH	DEPTH
I	SE side of dump	Bottom of dump	8.5 Ft.	9 Ft.
I	ESE side of dump	Bottom of dump	33 Ft.	13 Ft.
I	E side of dump	Bottom of dump	25 Ft.	8 Ft.
V	SW side of dump	Bottom of dump	8 Ft.	6 Ft.
V	SE side of dump	Bottom of dump	6.5 Ft.	4.5 Ft.
V	SE side of dump	Top of dump	9 Ft.	5 Ft.
		Bottom of dump	6 Ft.	5-1/2 Ft.

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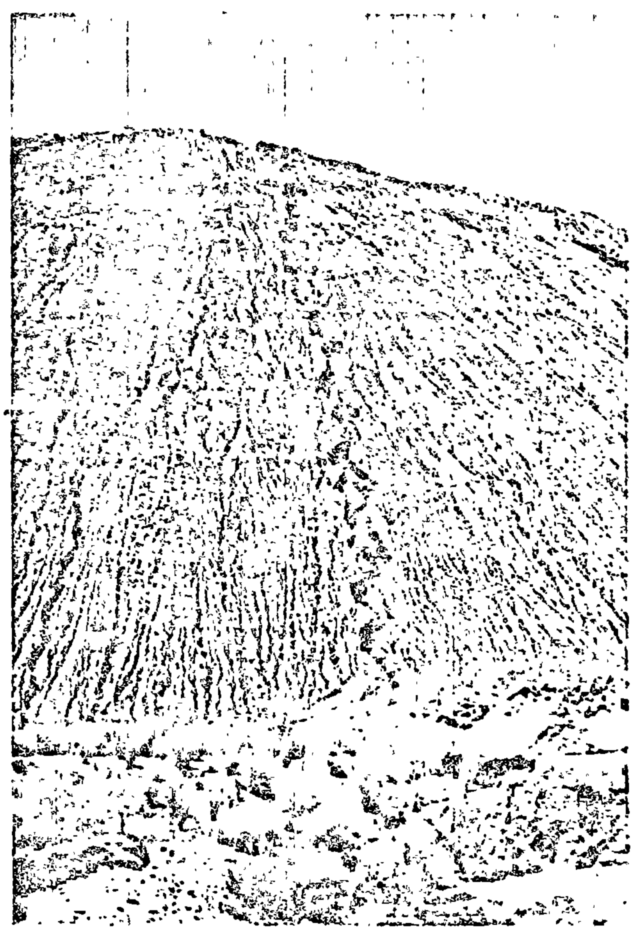

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FIGURE 2 - GULLY AT SOUTHEAST SIDE OF V DUMPOL-EPA01-0008596

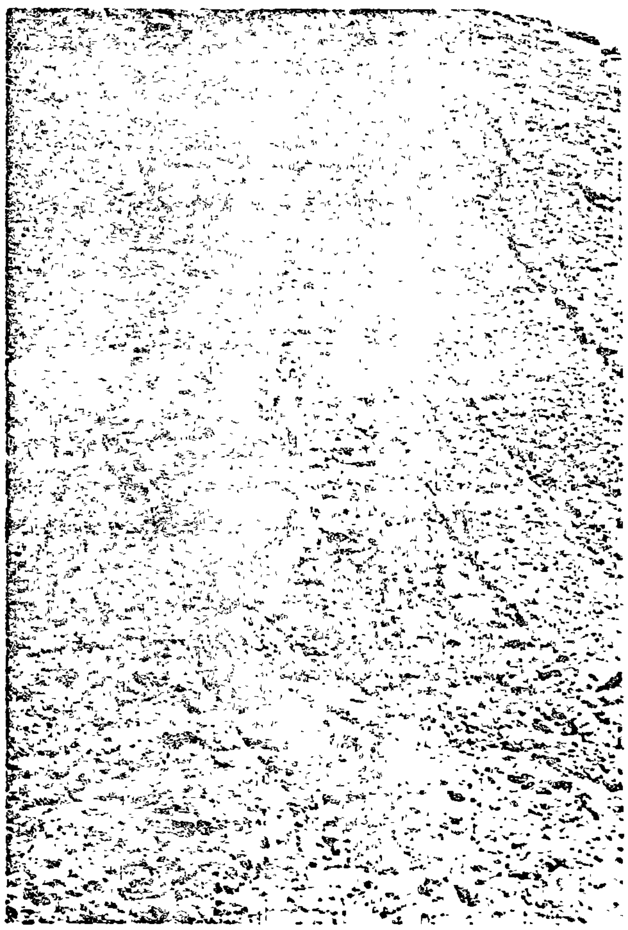

FIGURE 3 - GULLY AT SOUTHWEST SIDE OF V DUMP

FIGURE 4 - VIEW OF GULLY AT SOUTHEAST SIDE OF V DUMP
LOOKING DOWN FROM THE DUMP CREST.

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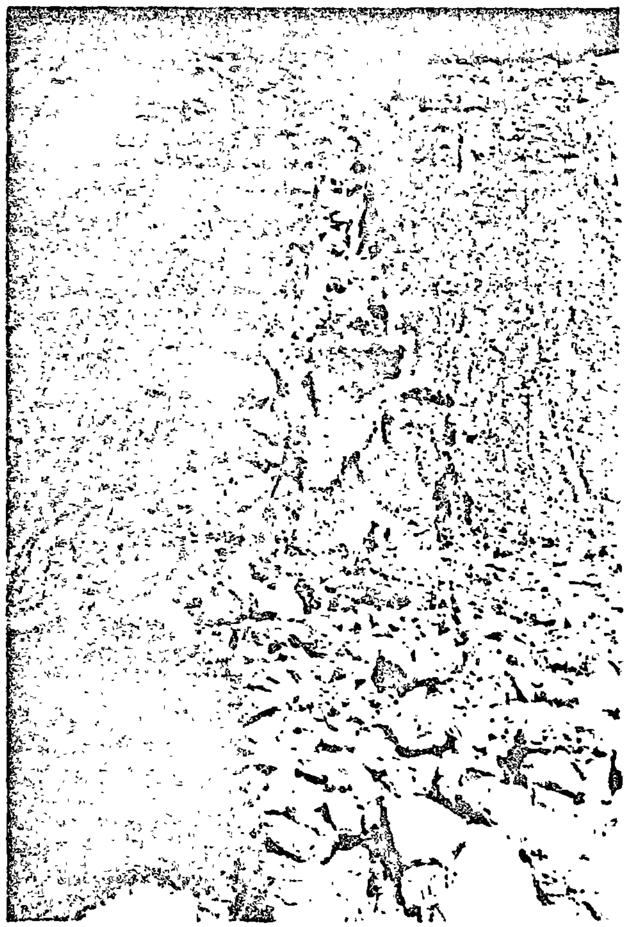

FIGURE 5 - GULLY AT SOUTHEAST SIDE OF I DUMP

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FIGURE 6 - GULLY AT EAST SIDE OF I DUMP

L = Slope length factor

S = Slope angle factor

C = Ground cover or vegetative factor

P = Erosion control factor (not applicable)

The USLE has several limitations to its use. Firstly, by definition, the equation applies a set of average values approximating site-specific conditions to predict erosion rates. Obviously, no empirically-derived equation can produce the accuracy of a site-specific erosion measurement program. Secondly, the equation predicts soil loss from sheetwash and small rill erosion only; gully erosion is not included, and tools to predict gully erosion do not exist. Thirdly, numerical values for the six variables in the equation were derived from measurement and computation of erosion rates on slopes less than 24 degrees, and slope lengths less than 400 feet. Applications of the USLE on slope angles and lengths greater than these is valid, however, the values of the variables are taken from curve extrapolations.

Soil loss from sheetwash and small rill erosion at 19 locations on 15 waste dumps at the the Jackpile-Paguate Mine has been calculated. Existing conditions of waste dump slopes were used to derive the variables used in the USLE. Anaconda (1980) cross-sections of dumps were used to calculate L and S; values of factors L and S for different dump slopes are given in Table 1. A grain size analysis of Tres Hermanos Sandstone "topsoil" material was used to assist in deriving factor K. Values of USLE variables and sources of information are given in Table 5.

Results of the USLE analysis are given in Table 6 in terms of tons of material lost per acre per year. Values range from a low of 22.5

TABLE 5

VALUES AND SOURCES OF VARIABLES USED IN UNIVERSAL SOIL LOSS EQUATION ANALYSIS

EQUATION: A = RK (LS) C P

VARIABLE	VALUE	SOURCE
R	25	U. S. Soil Conservation Service (1981)
P	1	U. S. Soil Conservation Service (1981)
C	.9	U. S. Soil Conservation Service (1981)
L	Variable (Depending on Dump; See Table I)	Anaconda (1980)
S	Variable (Depending on Dump; See Table I)	Anaconda (1980)
K	.125	U. S. Environmental Protection Agency (1977)

Assumptions for K factor derivations:

(1) % Silt and V. fine sand ≈ 20
(2) % Sand (.1 - 2mm) ≈ 50
(3) % Organics = 1%
(4) Soil structure = medium or coarse granular
(5) Permeability = moderate

TABLE 6

USLE CALCULATED SOIL LOSS FROM SHEETWASH ON WASTE DUMP SLOPES AT JACKPILE-PAGUATE MINE

DUMP	CROSS-SECTION	SLOPE PERCENT	SLOPE LENGTH	SOIL LOSS (TONS/ACRE/YEAR)
South	AA'	100	127 Ft.	137.8
South	BB'	100	198 Ft.	182.8
SP-1	DD'	78	51 Ft.	61.9
R	EE'	100	35 Ft.	61.9
T	FF'	77	164 Ft.	126.6
N	GG'	89	120 Ft.	120.9
N	HH'	77	76 Ft.	78.8
N	II'	50	89 Ft.	47.8
N2	JJ'	60	58 Ft.	47.8
FD-3	KK'	90	195 Ft.	165.9
U	LL'	75	100 Ft.	90.0
V	NN'	80	345 Ft.	196.9
V	OO'	71	258 Ft.	154.7
SP-2	PP'	89	60 Ft.	78.8
Y	QQ'	72	196 Ft.	123.8
Y2	RR'	75	249 Ft.	149.1
I	SS'	75	200 Ft.	135.0
	(3 Segments)	80	64 Ft.	73.1
		67	36 Ft.	42.2
FD-2	UU'	65	423 Ft.	168.8
S	--	25	164 Ft.	22.5

tons/acre/year at S Dump, to a high of 196.9 tons/acre/year at V Dump. It is apparent from inspection of Table 6, that accelerated soil loss correlates with steep slopes and long slope length; conversely erosion is inhibited on gentle and short slopes. Determination of the relative or absolute importance of slope percent vs. slope length in causing erosion has not been attempted in this study.

B. Rill and Gully Erosion:

Field measurements of the number, width, depth, and spacing of rills and gullies on several wate dump slopes were taken to describe existing erosional conditions. Rill and gully dimensions were measured along 200 foot transects parallel to contours of the dump slopes. Since the frequency and dimensions of rills and gullies varies from the toe to the crest of the dump slopes, two 200 foot transects were measured on each dump (except T Dump); the transects were run at approximately 1/3 and 2/3 of the distance from the toe to the crest of the dump slopes. The locations, widths, and depths of all channels were noted. Channels of less than six inches depth are considered rills in this study, while those of greater than 6 inches depth are considered gullies. Figure 7 gives the locations of all transects.

Thirteen transects were measured on seven waste dump slopes. A summary of total numbers of channels and their dimensions, together with slope age, slope percent, and slope length is given in Table 7. Histograms showing depths of channels for each dump slope measured are given in Figures 8 through 14. Total rill and gully erosion, measured as tons of material lost per acre, was computed for seven dump slopes using the standard U. S. Soil Conservation Service (1981) equation, and figures are

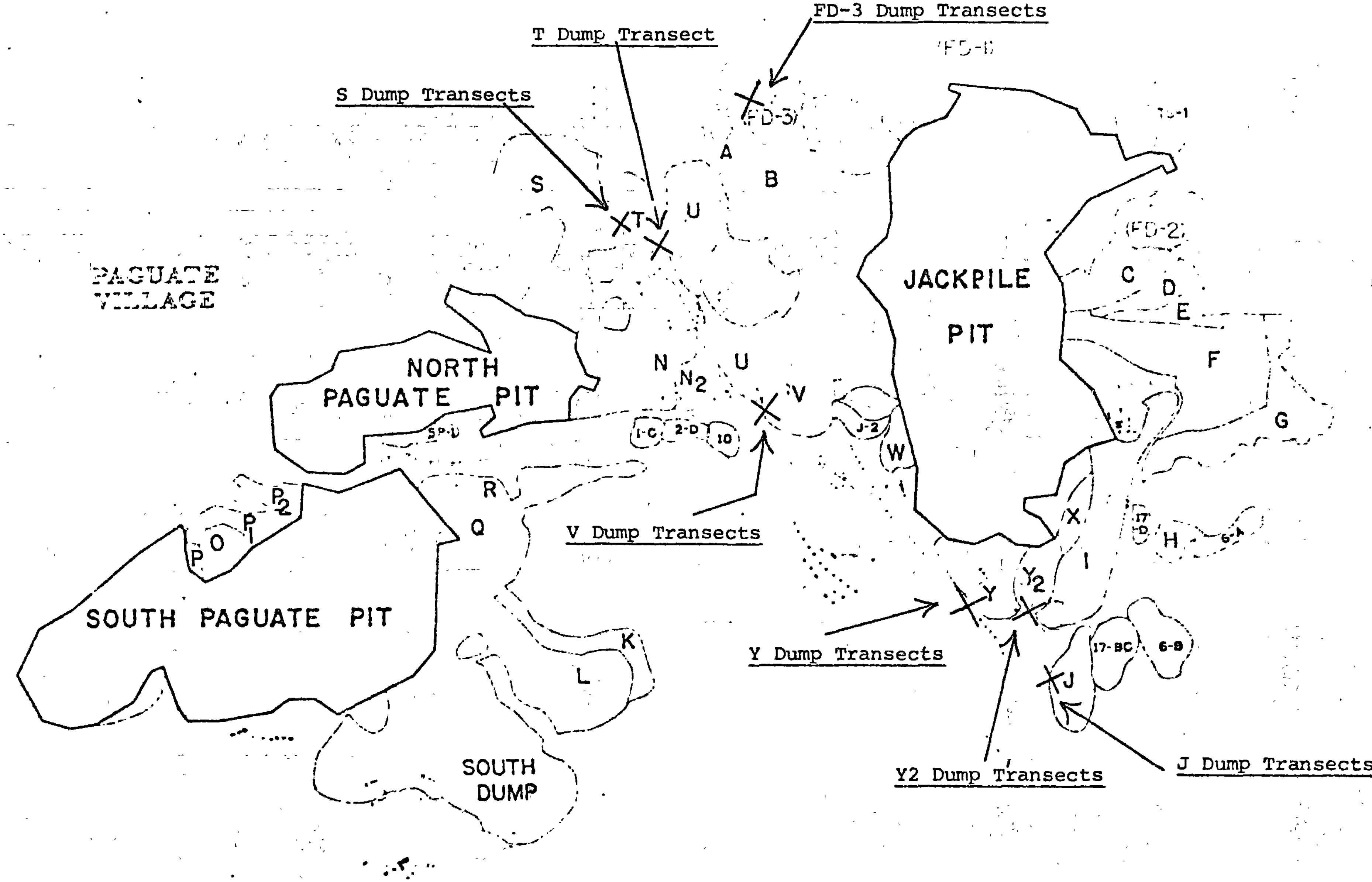


FIGURE 7

LOCATIONS OF TRANSECTS

TABLE 7

NUMBER AND DIMENSIONS OF RILLS AND GULLIES MEASURED IN 200 FOOT TRANSECTS ON WASTE DUMP SLOPES - JACKPILE-PAGUATE MINE

UPPER = Upper Transects
LOWER = Lower Transects
Rills = Channels $<$ 6 Inches Deep
Gullies = Channels $>$ 6 Inches Deep

DUMP	LAST MODIFIED	SLOPE PERCENT	LENGTH (FEET)	TOTAL CHANNELS	NUMBER RILLS,	MEAN WIDTH (INCHES)	MEAN DEPTH (INCHES)	NUMBER GULLIES	MEAN WIDTH (FEET)	MEAN DEPTH (FEET)
Y (UPPER)	Mid 1950's	72	196	33	18	5.0	3.1	15	4.7	1.4
Y (LOWER)	"	"	"	29	6	11.0	3.7	23	4.1	1.6
Y2 (UPPER)	Early 1960's	75	249	76	57	2.2	2.0	19	1.2	1.1
Y2 (LOWER)	"	"	"	66	42	2.2	1.9	24	1.1	1.1
V (UPPER)	≈ 1977	71	345	41	24	3.7	2.6	17	1.2	.9
V (LOWER)	"	71	"	54	28	4.1	2.4	26	1.4	1.0
FD-3 (UPPER)	≈ 1979	90	195	68	68	2.6	1.8	0	--	--
FD-3 (LOWER)	"	"	"	54	52	3.0	1.9	2	.8	1.0
*J (UPPER)	≈ 1977	73	130	95	91	1.9	2.0	4	3.7	7.0
*J (LOWER)	"	"	"	120	111	2.5	2.9	9	4.1	7.7
T	≈ 1978	77	164	86	82	3.2	1.8	4	12.0	6.0
*S (UPPER)	≈ 1979	25	164	22	22	2.5	1.1	0	--	--
*S (LOWER)	1979	"	"	36	36	2.9	1.1	0	--	--

*Denotes reclaimed dump

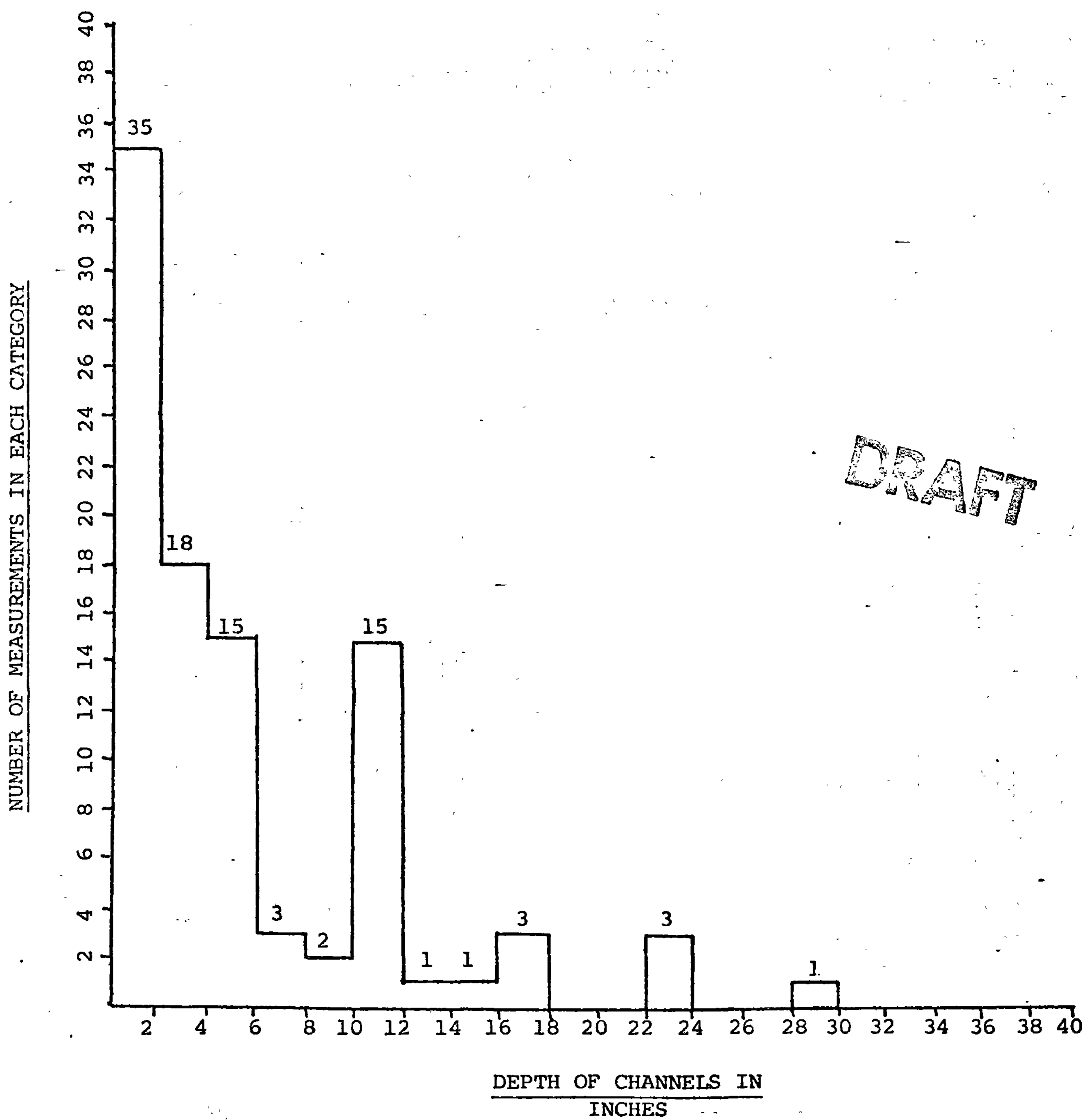
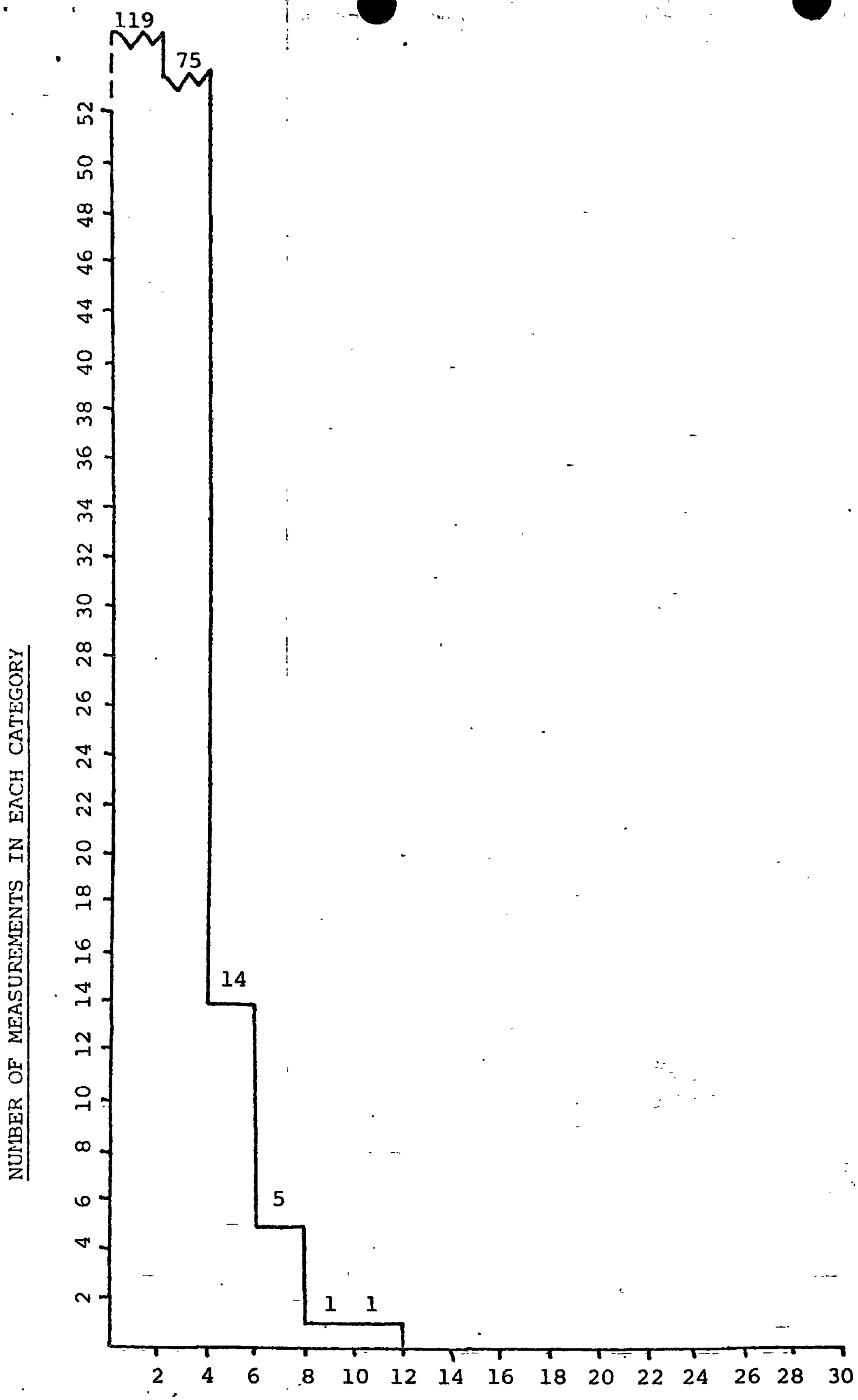


FIGURE 8

Histogram of depths of rill and gullies at V Dump near cross-section NN' of Anaconda (1980). Total Measurements (N) = 97.



DEPTH OF CHANNELS IN INCHES

FIGURE 9

Histogram of depths of channels on the west side of J Dump. Total measurements (N) = 215.

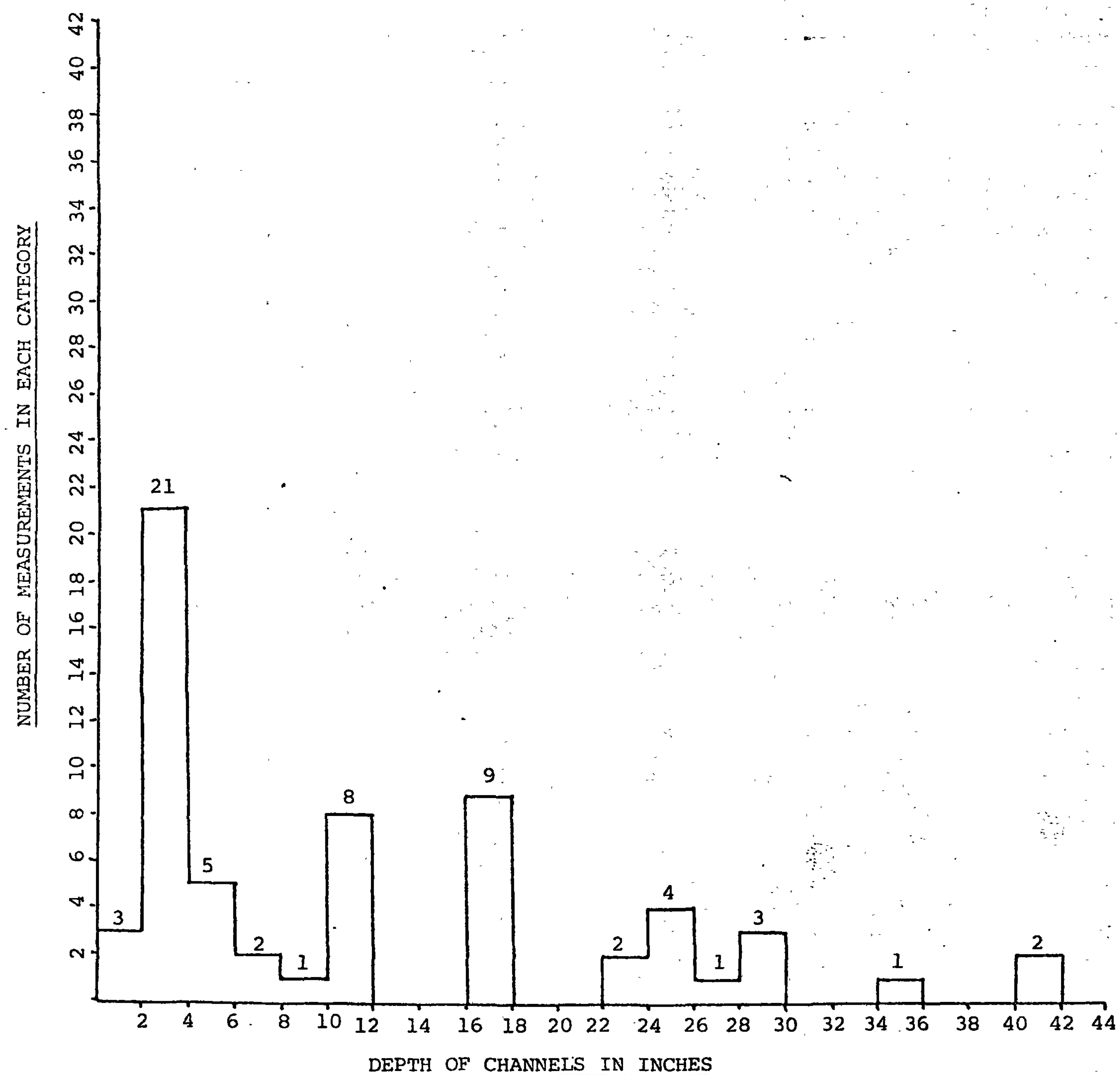


FIGURE 10

Histogram of depths of channels on Y Dump near cross-section QQ' of Anaconda (1980). Total measurements (N) = 62.

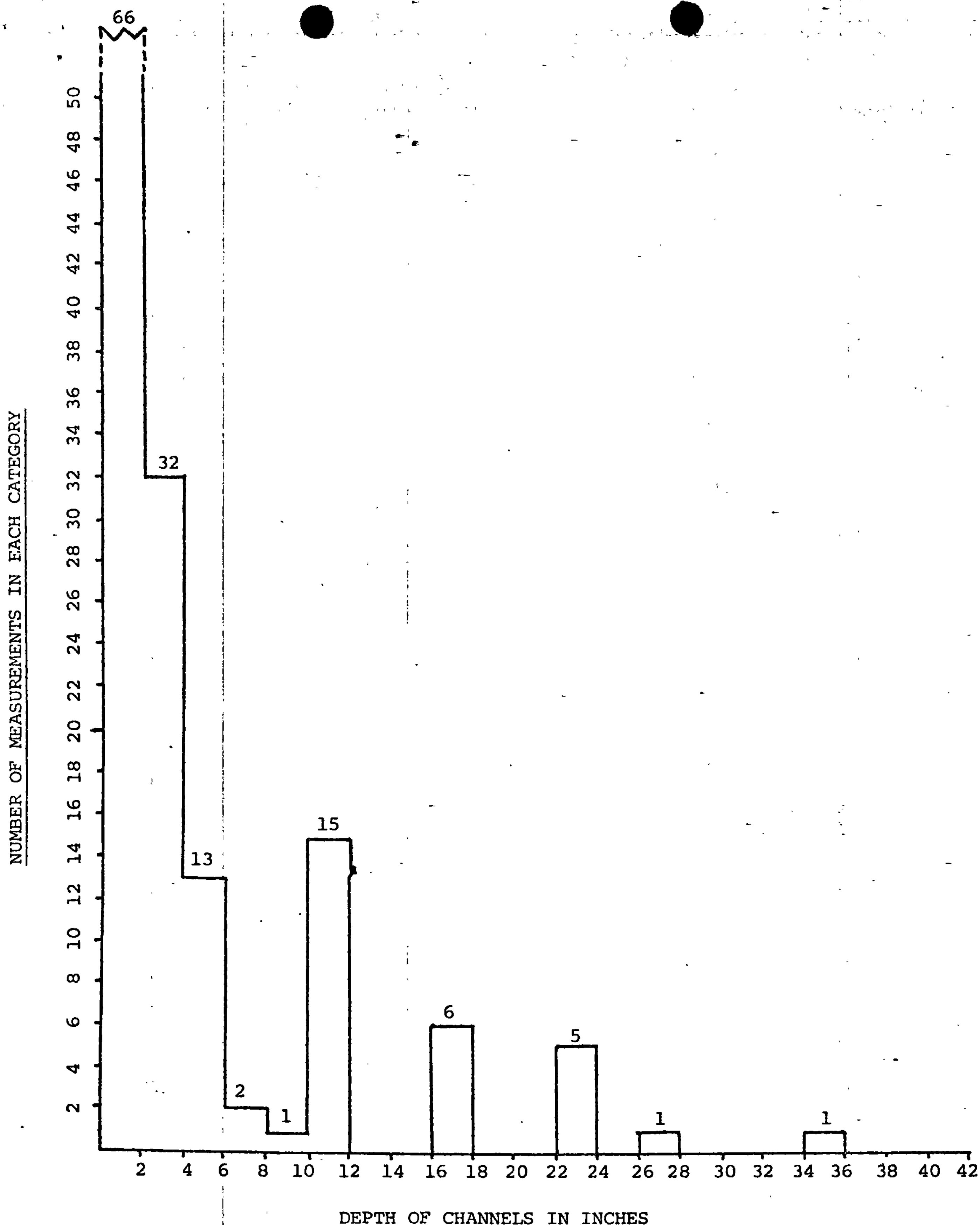


FIGURE 11

Histogram of depths of channels on Y2 Dump near cross-section RR' of Anaconda (1980). Total measurements (N) = 141.

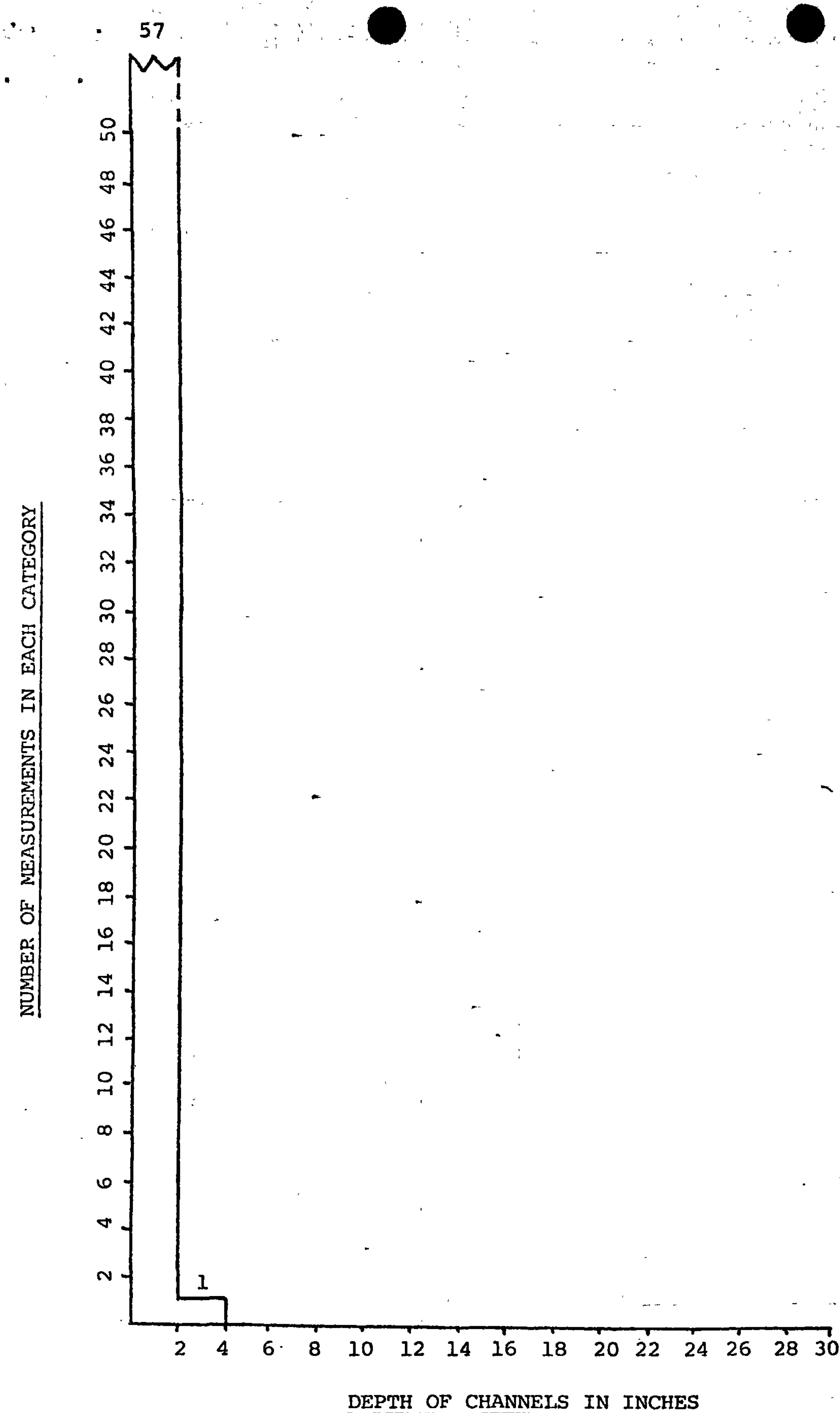


FIGURE 12

Histogram of depths of channels on the eastern side of S Dump. Total measurements (N) = 58.

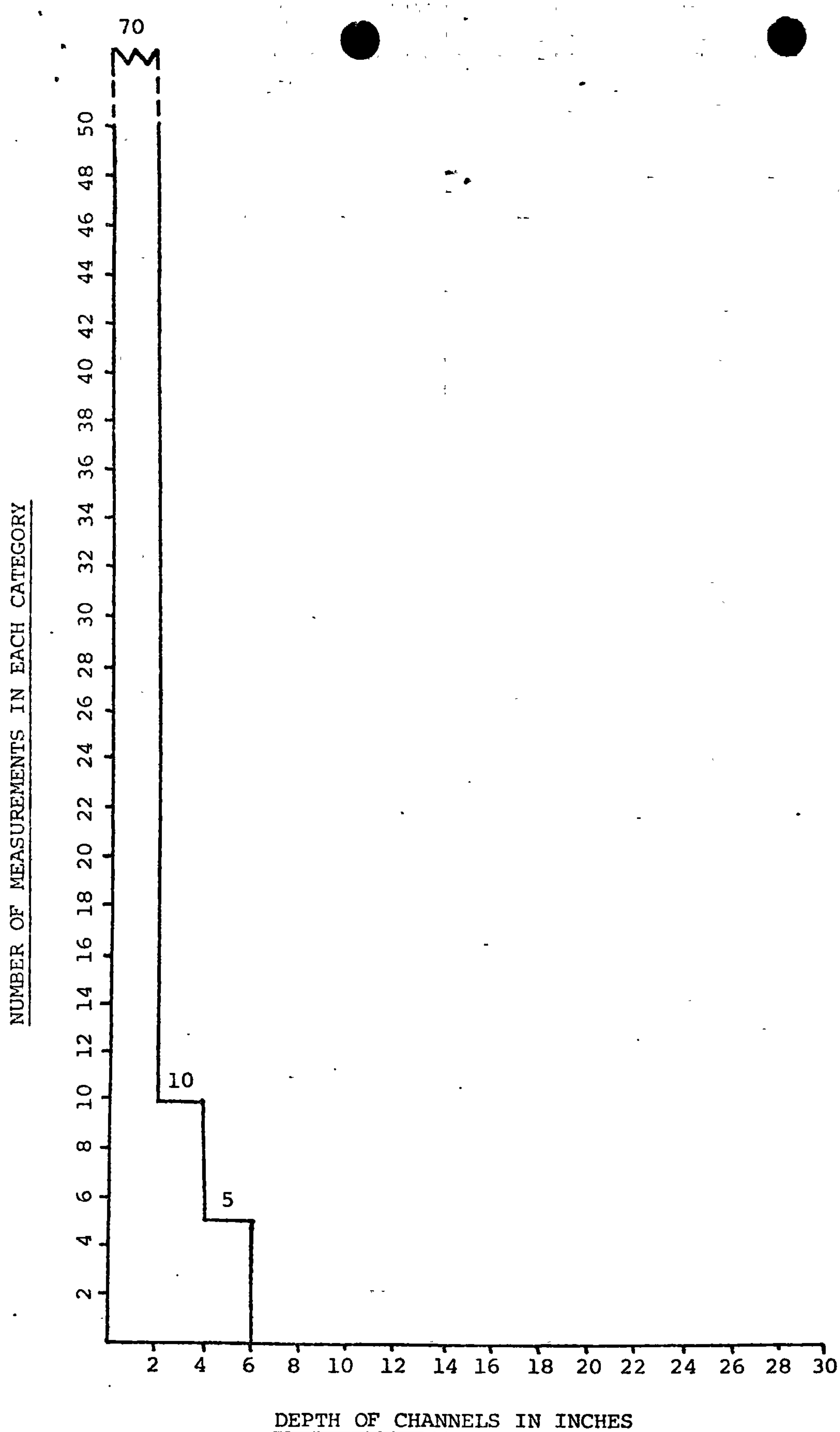


FIGURE 13

Histogram of depths of channels at T Dump near cross-section FF' of Anaconda (1980). Total measurements (N) = 85.

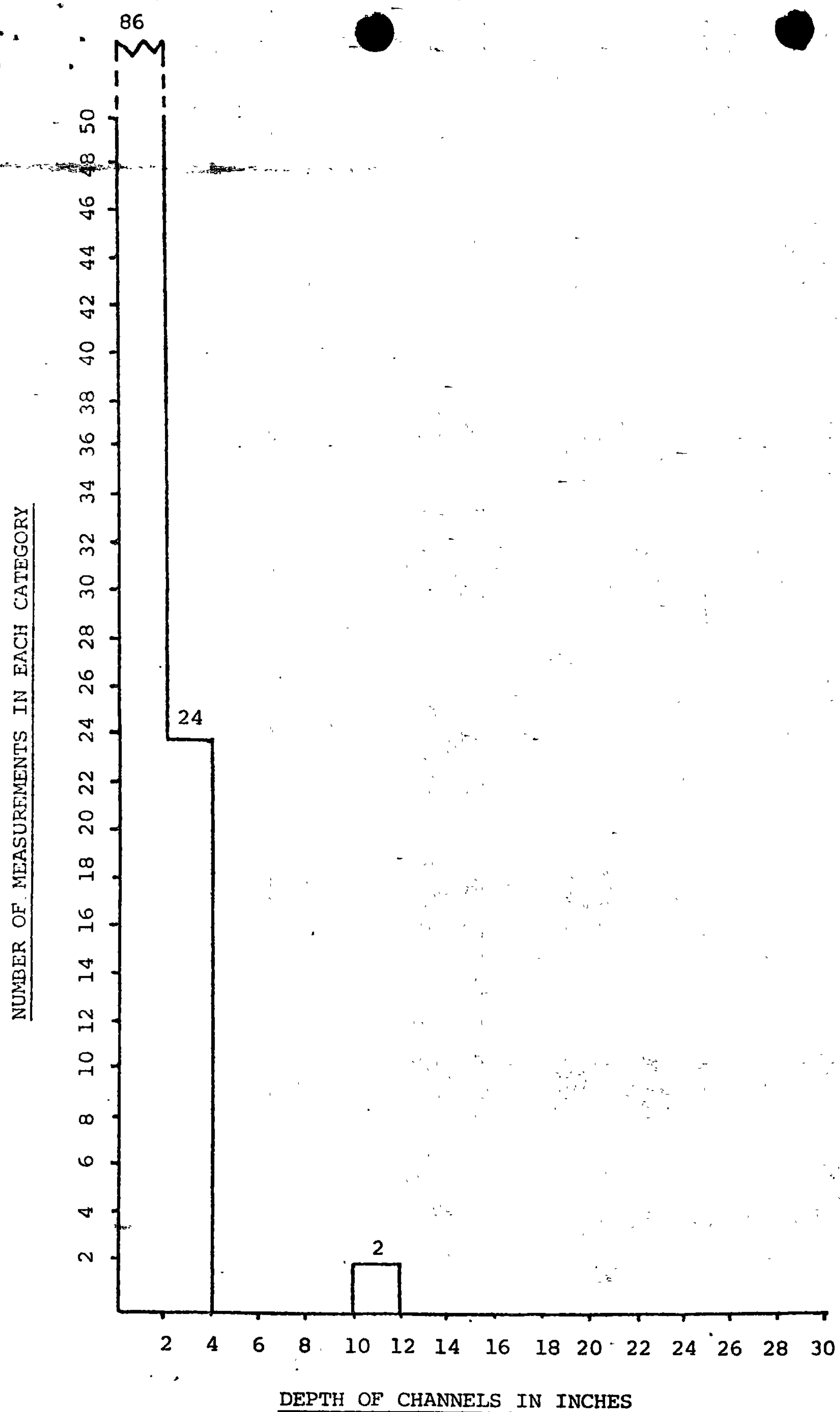


FIGURE 14

Histogram of depths of channels on FD-3 Dump near cross-section KK' of Anaconda (1980). Total measurements (N) = 112.

given in Table 8. The equation used in this computation converts cross-sectional areas of rills and gullies along 37.5 foot sections of the transects to tons of material eroded. The figures given in Table 8 are the means of erosion computed on four 37.5 foot sections per transect.

Dumps Y, Y2, V, and FD-3 form a "younging" series of dumps of approximately equal slope percent. Dump Y was last modified in the mid-1950's, Dump Y2 in the early 1960's, Dump V in 1977, and Dump FD-3 was last modified in the late 1979 to early 1980. Dump Y, the oldest dump at the mine, is the most severely eroded. Total number of rills (24) is low, however, mean width and depth of gullies is large (Table 7). and total erosion (Table 8) far exceeds the other dumps. Figures 15 and 16 give photographic evidence of this erosion. Total number of gullies on transects on V, Y2, and Y Dumps is roughly the same (Table 7); however, an increase in depth of gullies is noted with increasing age on these three slopes. Dump FD-3, a very recent dump, is essentially devoid of gullies at this point; however, rills are conspicuous on FD-3 Dump. Apparently, gully formation takes several years to initiate.

Total rill and gully erosion (Table 8) increases without exception with increasing age of waste dump slopes, as may be expected. However, since this increase is obviously not linear with age, other factors are clearly contributing to erosion rates. This study has not quantified the relative importance of factors influencing erosion; however, the data suggests that slope percent, slope length, and surface roughness are important. For example, comparison of total rill and gully erosion

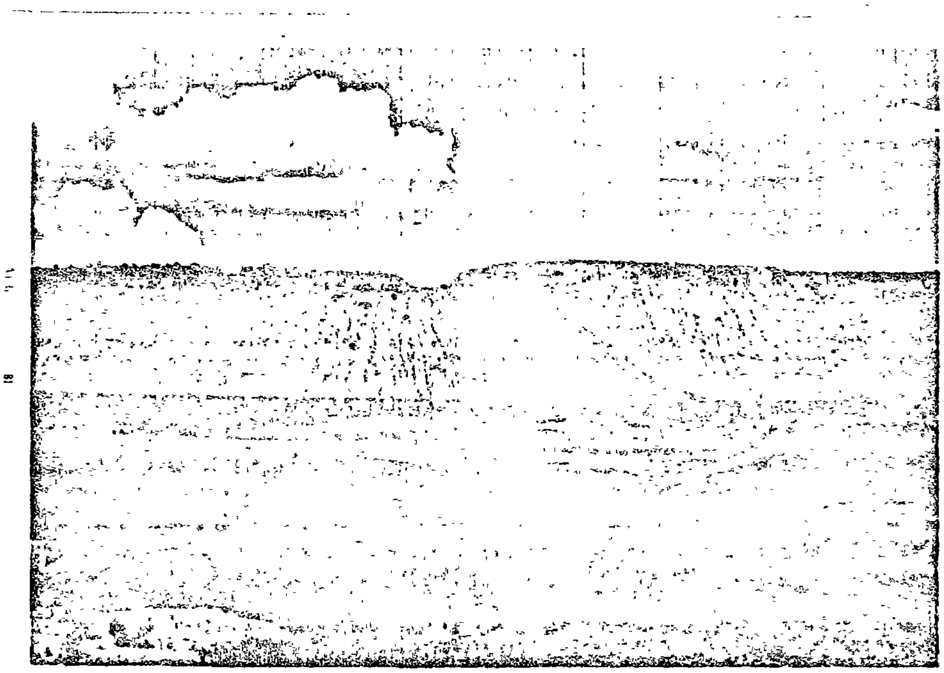


FIGURE 15 - DISSECTED Y DUMP AT LEFT OF PHOTO.

FIGURE 16 - GULLIES ON Y DUMP SLOPE.

TABLE 8

MEAN TOTAL RILL AND GULLY EROSION AT THE SEVEN WASTE DUMP SLOPES MEASURED*

DUMP	SLOPE AGE	SLOPE PERCENT	SLOPE LENGTH (FEET)	AMOUNT ERODED (TONS/ACRE)
Y	Mid 1950's	72	196	561
Y2	Early 1960's	75	249	172
V	≈ 1977	71	345	162
FD-3	≈ 1979	90	195	16
J	≈ 1977	73	~ 130	27
T	≈ 1978	77	164	24
S	≈ 1979	25	164	4

*Figures show total material lost from waste dump slopes computed by U. S. Soil Conservation Service (1981) equations.

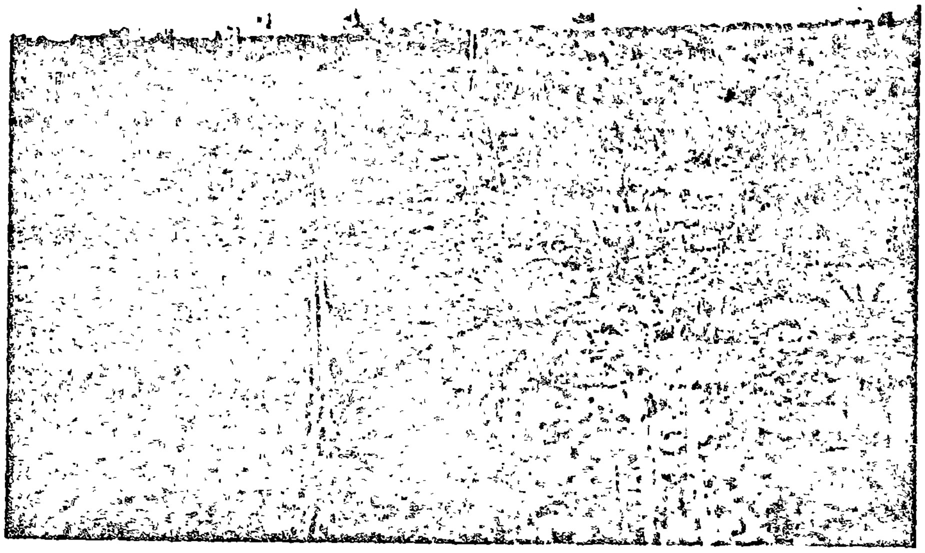
(Table 8) at Dumps V (unreclaimed, 71 percent slope, 1977 age, 345 feet length) and J (reclaimed, 73 percent slope, 1977 age, 130 feet length) suggests that the much greater amount of erosion at V Dump can be related to greater slope length and/or absence of reclamation.

Comparison of total rill and gully erosion (Table 8) at J and S Dumps - two reclaimed dumps of similar age and slope length - suggests that the greater amount of erosion at J Dump is due to much steeper slope gradient. For S Dump, the total number of measured channels, mean width, and depth of channels, and total computed rill and gully erosion was the least, of all dumps studied. Figure 17 shows photographic evidence of the lack of S Dump erosion. Presumably, the gentle (25 percent, 14 degree) slope is the primary factor inhibiting erosion at the S Dump.

Interestingly, total computed rill and gully erosion at J and T Dumps - dumps of similar age, slope percent, and slope length - is approximately equal, even though J has been reclaimed and T has not. This unexpected result - it would be expected that reclamation would greatly inhibit erosion - may be the result of the significant surface roughness caused by boulder-sized material at T Dump. Surface roughness tends to dissipate energy of moving water, thereby reducing erosion. Surface roughness clearly inhibits rill and gully formation, and promotes vegetative success at several waste dumps (Figure 18).

III. CONCLUSIONS:

Waste dumps at the Jackpile-Paguate Mine constitute a significant and definable hazard in the form of erosional instability and possible resultant exposure of radiological material. All waste dumps have been



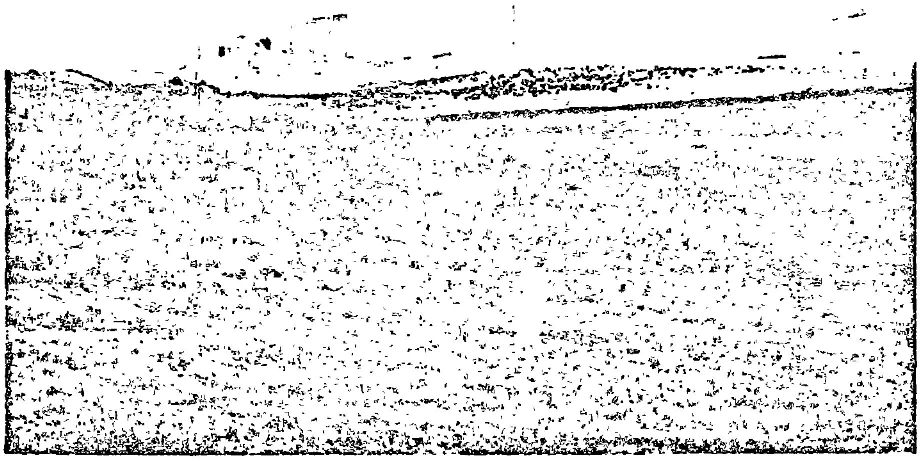


FIGURE 17 - Photographs of S Dump showing lack of rills and gullies.

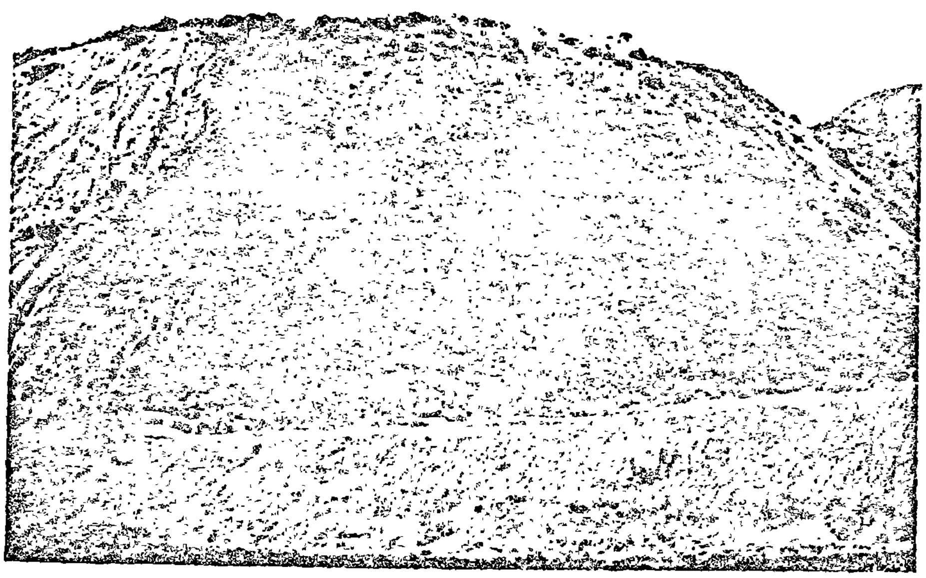


FIGURE 18 - Y DUMP. BOULDERY SLOPES IN CENTER OF PHOTO PROMOTE VEGETATIVE SUCCESS AND RETARD EROSION RELATIVE TO SANDY SLOPES TO THE LEFT.

cut by numerous rills and gullies. The steeper dumps have been cut by large gullies, greater than eight feet wide and six feet deep. It is clear that significant waste dump modifications will have to take place if erosional stability of dump slopes is to occur.

Universal Soil Loss Equation (USLE) analysis of dump slopes shows that significant sheetwash and small rill erosion is occurring. Waste dump slope percent and length seem to be the major factors controlling sheetwash and small rill erosion. The least amount of computed erosion occurs on the most gentle slopes. Comparison of USLE-derived erosion rates for sheetwash (Table 6) with total rill and gully erosion (Table 8) leads to the conclusion that sheetwash is the process responsible for the majority of erosion on dump slopes.

However, field measurements and observations show that rill and gully erosion is well-developed, and is capable of cutting deeply into dump slopes. Slope percent, length of slopes, age, and surface roughness seem to be the factors controlling rill and gully erosion. The least amount of rill and gully erosion has occurred on the most gentle slope measured. Previous reclamation efforts have failed to institute adequate vegetative cover to successfully retard significant rill and gully formation. Surface roughness has apparently retarded erosion as much as reclamation efforts have.

This study has documented erosional conditions at mine-site waste dumps. The severity of erosion on the dump slopes dictates that, unless significant slope modifications are made, revegetation-reclamation success is highly unlikely. Slope modifications should include increasing surface roughness, decreasing slope percent, and decreasing slope length. The reduction of slope percent is seen as the modification most crucial to reclamation success.

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